

CHAPTER 4

BATTERIES

INTRODUCTION

A battery consists of a number of cells assembled in a common container and connected together to function as a source of electrical power. This chapter introduces the basic theory and characteristics of batteries. The batteries discussed are representative of the many models and types used in the Army.

The cell is the building block of all batteries. This chapter explains the physical makeup of the cell and the methods used to combine cells to provide useful voltage, current, and power. The chemistry of the cell and how chemical action is used to convert chemical energy to electrical energy are also discussed. In addition, this chapter addresses the care, maintenance, and operation of batteries, as well as some of the safety precautions that should be followed while working around batteries.

Batteries are widely used as sources or direct current electrical energy in automobiles, boats, aircraft, shops, portable electric/electronic equipment, and lighting equipment. In some instances, batteries are used as the only source of power. In others, they are used as a secondary or emergency power source.

BATTERY COMPONENTS

The Cell

A cell is a device that transforms chemical energy into electrical energy. Figure 4-1 shows the simplest cell, known as a galvanic or voltaic cell. It consists of a piece of carbon (C) and a piece of zinc (Zn) suspended in a jar that contains a sulfuric acid solution (H_2SO_4), called the electrolyte.

The cell is the fundamental unit of the battery. A simple cell consists of two electrodes placed in a container that holds the electrolyte. In some cells, the container acts as one of the electrodes and is acted upon by the electrolyte.

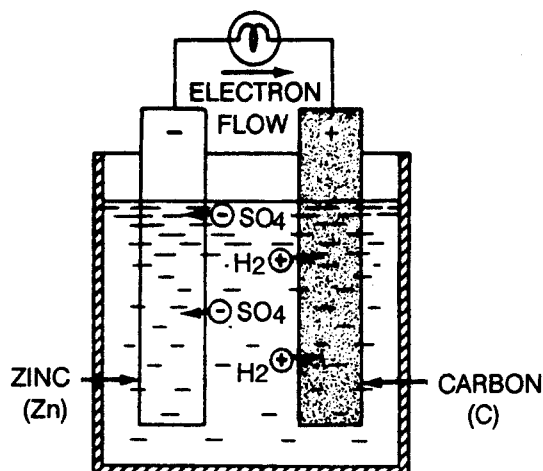


FIGURE 4-1. Simple Voltaic or Galvanic Cell.

Electrodes

The electrodes are the conductors by which the current leaves or returns to the electrolyte. In the simple cell, they are carbon and zinc strips placed in the electrolyte. In the dry cell (Figure 4-2), they are the carbon rod in the center and zinc container in which the cell is assembled.

Electrolyte

The electrolyte is the solution that reacts with the electrodes. The electrolyte provides a path for electron flow. It may be a salt, an acid, or an alkaline solution. In the simple galvanic cell, the electrolyte is a liquid. In the dry cell, the electrolyte is a paste.

Container

The container provides a means of holding (containing) the electrolyte. It is also used to mount the electrodes. The container may be constructed of one of many different materials. In the voltaic cell, the container must be constructed of a material that will not be acted upon by the electrolyte.

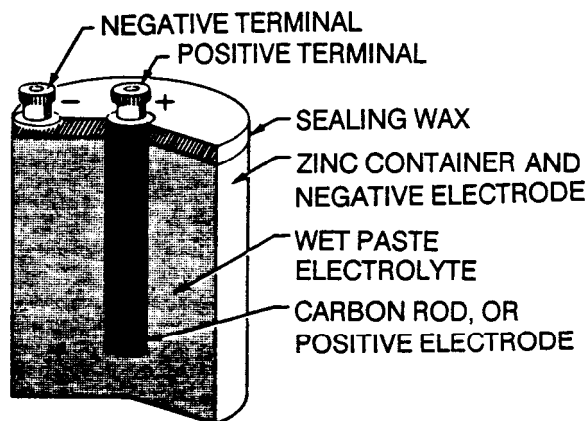


FIGURE 4-2. Dry Cell, Cross-Sectional View.

PRIMARY AND SECONDARY CELLS

Primary Cell

In a primary cell, the chemical action eats away one of the electrodes, usually the negative electrode. When this happens, the electrode must be replaced or the cell must be discarded. In a galvanic-type cell, the zinc electrode and the liquid electrolyte are usually replaced. It is usually cheaper to buy a new dry cell than it is to repair it.

Secondary Cell

In a secondary cell, the electrodes and electrolyte are altered by the chemical action that takes place when the cell delivers current. A secondary cell may be restored to its original condition by forcing an electric current through it in the direction opposite to that of discharge. The automobile storage battery is a common example of a secondary cell.

ELECTROCHEMICAL ACTION

When a load, a device that consumes electrical power, is connected to the electrodes of a charged cell, electrons will move from the cathode (negative electrode) toward the anode (positive electrode). The conversion of the cell's chemical energy to a productive electrical energy is called electrochemical action.

The voltage across the electrodes depends on the materials the electrodes are made of and the composition of the electrolyte. The current a cell delivers depends on the resistance of the entire circuit, including the cell itself. The internal resistance of the cell depends on the size of the electrodes, the distance between them in the electrolyte, and the resistance of the electrolyte. The larger the electrodes and the nearer their proximity in the electrolyte (without touching), the lower the internal resistance of the cell. The lower the internal cell resistance, the smaller the voltage loss within the cell while delivering current.

Primary Cell Chemistry

When a current flows through a primary cell having carbon and zinc electrodes and a diluted solution of sulfuric acid and water (combined to form the electrolyte), the following chemical reaction takes place. The current flow through the load is the movement of electrons from the negative electrode (zinc) of the cell to the positive electrode (carbon). This causes fewer electrons in the zinc and an excess of electrons in the carbon. Figure 4-1 shows the hydrogen ions (H_2) from the sulfuric acid being attracted to the carbon electrode. Since the hydrogen ions are positively charged, they are attracted to the negative charge on the carbon electrode. The excess of electrons causes this negative charge. The zinc electrode has a positive charge because it has lost electrons to the carbon electrode. This positive charge attracts the negative ions (SO_4) from the sulfuric acid. The negative ions combine with the zinc to form zinc sulfate. This action causes the zinc electrode to be eaten away. Zinc sulfate is a grayish-white substance that is sometimes seen on the battery post of an automobile battery.

The process of the zinc being eaten away and the sulfuric acid changing to hydrogen and zinc sulfate causes the cell to discharge. When the zinc is used up, the voltage of the cell is reduced to zero.

In Figure 4-1, the zinc electrode is labeled negative, and the carbon electrode is labeled positive. This represents the current flow outside the cell from negative to positive.

The zinc combines with the sulfuric acid to form zinc sulfate and hydrogen. The zinc sulfate dissolves in the electrolyte (sulfuric acid and water), and the hydrogen appears as gas bubbles around the

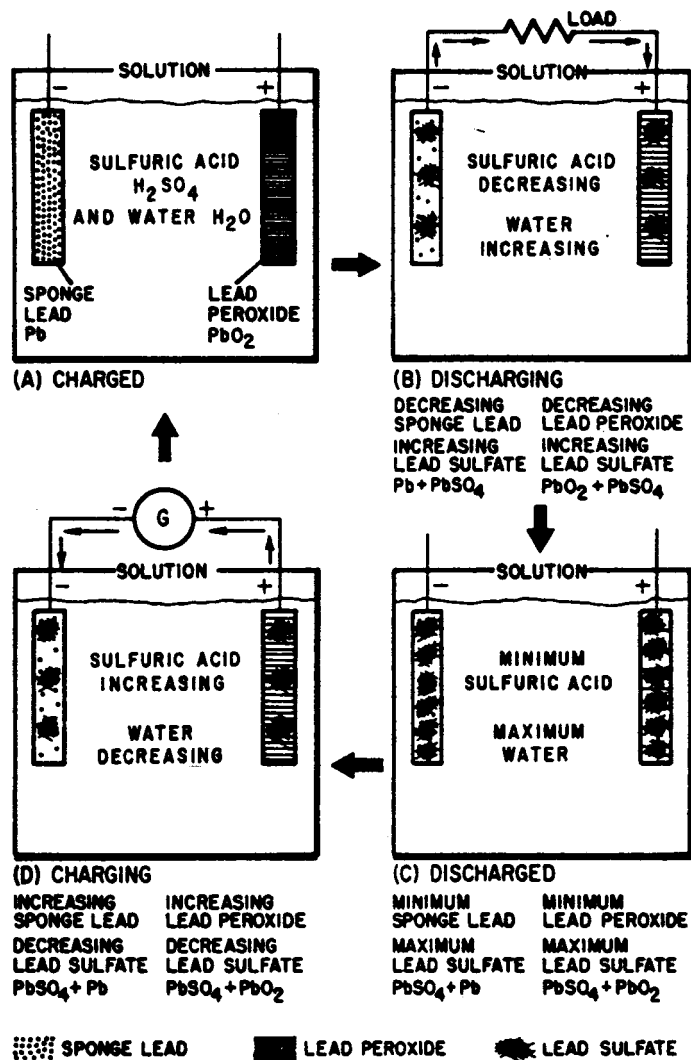


FIGURE 4-3. Secondary Cell.

carbon electrode. As current continues to flow, the zinc gradually dissolves, and the solution changes to zinc sulfate and water. The carbon electrode does not enter into the chemical changes taking place but simply provides a return path for the current.

Secondary Cell Chemistry

The secondary cell in Figure 4-3 uses sponge lead as the cathode and lead peroxide as the anode. This lead-acid cell is used to explain the general chemistry of the secondary cell. The materials that make up other types of secondary cells are different, but the chemical action is basically the same.

View A shows a fully charged, lead-acid secondary cell. The cathode is pure sponge lead. The anode is pure lead peroxide. The electrolyte is a mixture of sulfuric acid and water.

View B shows the secondary cell discharging. A load is connected between the cathode and anode. Current flows negative to positive. This current flow creates the same process found in the primary cell with the following exceptions. In the primary cell, the zinc cathode was eaten away by the sulfuric acid. In the secondary cell, the sponge-like construction of the cathode retains the lead sulfate formed by the chemical action of the sulfuric acid and the lead. In the primary cell, the carbon anode was not chemically

acted on by the sulfuric acid. In the secondary cell, the lead peroxide anode is chemically changed to lead sulfate by the sulfuric acid.

View C shows a fully discharged Cell. The anode and cathode retain some lead peroxide and sponge lead, but the amounts of lead sulfate in each is maximum. The electrolyte has a minimum amount of sulfuric acid. With this condition, no further chemical action can take place within the cell.

A secondary cell can be recharged. This is the process of reversing the chemical action that occurs as the cell discharges. To recharge the cell, a voltage source, such as a generator, is connected (view D). The negative terminal of the voltage source is connected to the cathode of the cell, and the positive terminal of the voltage source is connected to the anode of the cell. This arrangement chemically changes the lead sulfate back to sponge lead in the cathode, lead peroxide in the anode, and sulfuric acid in the electrolyte. After all the lead sulfate is chemically changed, the cell is fully charged (view A). Then the discharge-charge cycle may be repeated.

POLARIZATION OF THE CELL

The chemical action that occurs in the cell while the current is flowing causes hydrogen bubbles to form on the surface of the anode. This action is called polarization. Some hydrogen bubbles rise to the surface of the electrolyte and escape into the air. Some remain on the surface of the anode. If enough bubbles remain around the anode, the bubbles form a barrier that increases internal resistance. When the internal resistance of the cell increases, the output current decreases and the voltage of the cell also decreases.

A cell that is heavily polarized has no useful output. There are several methods to prevent polarization or to depolarize the cell. One method uses a vent on the cell to let the hydrogen escape into the air. A disadvantage of this method is that hydrogen is not available to reform into the electrolyte during recharging. This problem is solved by adding water to the electrolyte, such as in an automobile battery. A second method uses a material rich in oxygen, such as manganese dioxide, to supply free oxygen to combine with the hydrogen and form water. A third method uses a material, such as calcium, to absorb the hydrogen. The calcium releases hydrogen during the charging process. All

three methods remove enough hydrogen so that the cell is practically free from polarization.

LOCAL ACTION

When the external circuit is removed, the current ceases to flow, and theoretically, all chemical action within the cell stops. However, commercial zinc contains many impurities, such as iron, carbon, lead, and arsenic. These impurities form many small electrical cells within the zinc electrode in which current flows between the zinc and its impurities. Thus, the chemical action continues even though the cell itself is not connected to a load. Removing and controlling impurities in the cell greatly increases the life of the battery.

TYPES OF CELLS

The development of new and different types of cells in the past decade has been so rapid it is almost impossible to have a complete knowledge of all the various types. A few recent developments are the silver-zinc, nickel-zinc, nickel-cadmium, silver-cadmium, organic, inorganic, and mercury cells.

Primary Dry Cell

The dry cell is the most popular type of primary cell. It is ideal for simple applications where an inexpensive and noncritical source of electricity is all that is needed. The dry cell is not actually dry. The electrolyte is not in a liquid state, but it is a moist paste. If it should become totally dry, it would no longer be able to transform chemical energy to electrical energy.

Figure 4-4 shows the construction of a common type of dry cell. The internal parts of the cell are located in a cylindrical zinc container. This zinc container serves as the negative electrode (cathode) of the cell. The container is lined with a nonconducting material, such as blotting paper, to separate the zinc from the paste. A carbon electrode in the center serves as the positive terminal (anode) of the cell. The paste is a mixture of several substances, such as ammonium chloride, powdered coke, ground carbon, manganese dioxide, zinc chloride, graphite, and water. It is packed in the space between the anode and the blotting paper. The paste also serves to hold the anode rigid in the center of the cell. When the paste is packed in the cell, a small space is left at

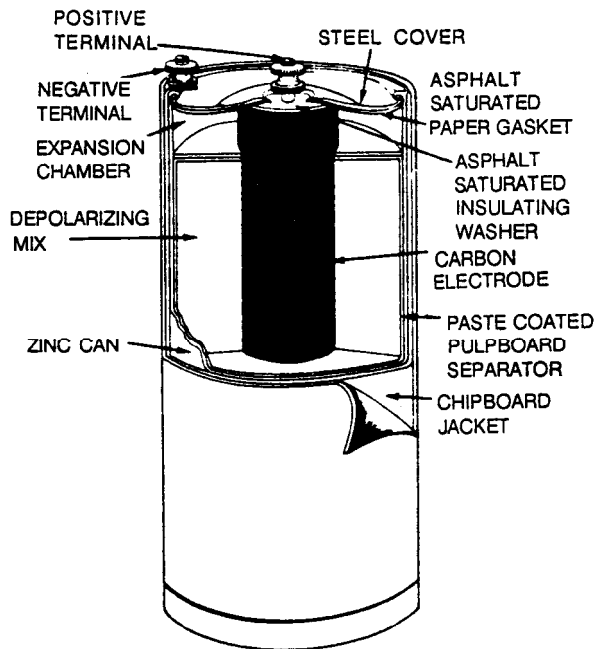


FIGURE 4-4. Cutaway View of the General-Purpose Dry Cell.

the top for expansion of the electrolytic paste caused by the depolarization action. The cell is then sealed with a cardboard or plastic seal.

Since the zinc container is the cathode, it must be protected with some insulating material to be electrically isolated. Therefore, it is common practice for the manufacturer to enclose the cells in the cardboard and metal containers.

The dry cell (Figure 4-4) is basically the same as the simple voltaic cell (wet cell) as far as its internal chemical action is concerned. The action of the water and the ammonium chloride in the paste, together with the zinc and carbon electrodes, produces the voltage of the cell. Manganese dioxide is added to reduce polarization when current flows, and zinc chloride reduces local action when the cell is not being used.

A cell that is not being used (sitting on the shelf) will gradually deteriorate because of slow internal chemical changes (local action). This deterioration is usually very slow if cells are properly

stored. If unused cells are stored in a cool place, their shelf life will be greatly increased. Therefore, to minimize deterioration, they should be stored in refrigerated spaces.

The blotting paper (paste-coated pulpboard separator) serves two purposes:

- It keeps the paste from actually contacting the zinc container.
- It lets the electrolyte from the paste filter through to the zinc slowly.

The cell is sealed at the top to keep air from entering and drying the electrolyte. Care should be taken to prevent breaking this seal.

Secondary Wet Cells

Secondary cells are sometimes known as wet cells. There are four basic types of wet cells: lead-acid, nickel-cadmium, silver-zinc, and silver-cadmium. Different combinations of materials are used to form the electrolyte, cathode, and anode of different cells. These combinations provide the cells with different qualities for many varied applications.

Lead-Acid Cell. The lead-acid cell is the most widely used secondary cell. The previous explanation of the secondary cell describes how the lead-acid cell provides electrical power. The discharging and charging action presented in Electrochemical Action describes the lead-acid cell. The lead-acid cell has an anode of lead peroxide, a cathode of sponge lead, and an electrolyte of sulfuric acid and water.

Nickel-Cadmium Cell. The nickel-cadmium (NICAD) cell is far superior to the lead-acid cell. In comparison to lead-acid cells, these cells generally require less maintenance throughout their service life regarding the addition of electrolyte or water. The major difference between the nickel-cadmium cell and the lead-acid cell is the material used in the cathode, anode, and electrolyte. In the nickel-cadmium cell, the cathode is cadmium hydroxide; the anode is nickel hydroxide; and the electrolyte is potassium hydroxide and water.

The nickel-cadmium and lead-acid cells have capacities that are comparable at normal discharge rates. However, at higher discharge rates, the

nickel-cadmium cell can deliver a large amount of power. Also, the nickel-cadmium cell can –

- Be charged in a shorter time.
- Stay idle longer in any state of charge and keep a full charge when stored for a longer period of time.
- Be charged and discharged any number of times without any appreciable damage.

Because of their superior capabilities, nickel-cadmium cells are used extensively in many military applications that require a cell with a high discharge rate. A good example is in the LACV-30 storage battery.

Silver-Zinc Cells. The silver-zinc cell is used extensively to power emergency equipment. However, it is relatively expensive and can be charged and discharged fewer times than other types of cells. When compared to lead-acid or nickel-cadmium cells, these disadvantages are outweighed by the light weight, small size, and good electrical capacity of the silver-zinc cell. The silver-zinc cell uses the same electrolyte as the nickel-cadmium cell (potassium hydroxide and water), but the anode and cathode differ. The anode is made of silver oxide, and the cathode is made of zinc.

Silver-Cadmium Cell. The silver-cadmium cell is a recent development for use in storage batteries. The silver-cadmium cell combines some of the better features of the nickel-cadmium and silver-zinc cells. It has more than twice the shelf life of the silver-zinc cell and can be recharged many more times. The disadvantages of the silver-cadmium cell are high cost and low voltage production. The electrolyte of the silver-cadmium cell is potassium hydroxide and water as in the nickel-cadmium and silver-zinc cells. The anode is silver oxide as in the silver-zinc cell, and the cathode is cadmium hydroxide as in the NICAD cell.

BATTERIES AS POWER SOURCES

A battery is a voltage source that uses chemical action to produce a voltage. The term “battery” is often applied to a single cell, such as the flashlight battery. In a flashlight that uses a battery of 1.5 volts, the battery is a single cell. The flashlight that is operated by 6 volts uses four cells in a single case.

This is a battery composed of more than one cell. Cells can be combined in series or in parallel.

In many cases, a battery-powered device may require more electrical energy than one cell can provide. The device may require a higher voltage or more current, or, in some cases, both. To meet the higher requirements, a sufficient number of cells must be combined or interconnected. Cells connected in series provide a higher voltage, while cells connected in parallel provide a higher current capacity.

Series-Connected Cells

Assume that a load requires a power supply of 6 volts and a current capacity of 1/8 ampere. Since a single cell normally supplies a voltage of only 1.5 volts, more than one cell is needed. To obtain the higher voltage, the cells are connected in series, as shown in Figure 4-5. Figure 4-5 view B is a schematic representation of the circuit in view A. The load is shown by the lamp symbol, and the battery is indicated by one long and one short line per cell.

In a series hookup, the negative electrode (cathode) of the first cell is connected to the positive

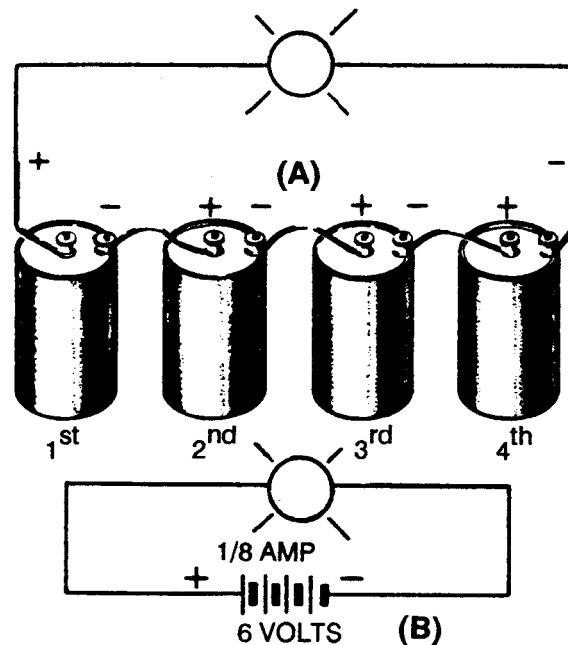


FIGURE 4-5. Series-Connected Cells.

electrode (anode) of the second cell, the negative electrode of the second to the positive of the third, and so on. The positive electrode of the first cell and negative electrode of the last cell then serve as the terminals of the battery. In this way, the voltage is 1.5 volts for each cell in the series line. There are four cells, so the output terminal voltage is 1.5×4 or 6 volts. When connected to the load, $1/8$ ampere flows through the load and each cell of the battery. This is within the capacity of each cell. Therefore, only four series-connected cells are needed to supply this particular load.

WARNING

When connecting cells in series, there MUST ALWAYS be two unconnected terminals remaining. These two terminals must be connected to each side of a load. NEVER connect the final two remaining terminals together unless a load is placed between them. Physical harm or equipment damage will result.

Parallel-Connected Cells

Assume an electrical load requires only 1.5 volts but will require $1/2$ ampere of current. (Assume that a single cell will supply only $1/8$ ampere.) To meet this requirement, the cells are connected in parallel, as shown in Figure 4-6 view A and schematically represented in view B. In a parallel connection, all positive cell electrodes are connected to one line, and all negative electrodes are connected to the other. No more than one cell is connected between the lines at any one point, so the voltage between the lines is the same as that of one cell, or 1.5 volts. However, each cell may contribute its maximum allowable current of $1/8$ ampere to the line. There are four cells, so the total line current is $1/8 \times 4$, or $1/2$ ampere. In this case, four cells in parallel have enough capacity to supply a load requiring $1/2$ ampere at 1.5 volts.

BATTERY CONSTRUCTION

Secondary cell batteries are constructed using the various secondary cells already described. The lead-acid battery, one of the most common batteries, will be used to explain battery construction. The

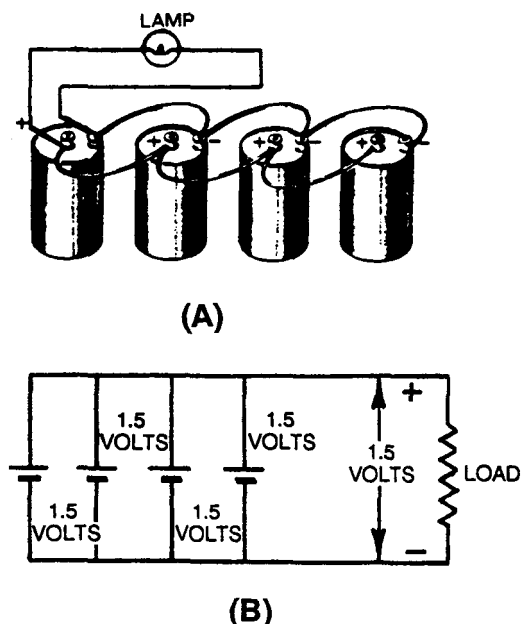


FIGURE 4-6. Parallel-Connected Cells.

nickel-cadmium battery, which is being used with increasing frequency, will also be discussed.

Figure 4-7 shows the makeup of a lead-acid battery. The container houses the separate cells. Most containers are hard rubber, plastic, or some other material that is resistant to the electrolyte and mechanical shock and can withstand extreme temperatures. The container (battery case) is vented through vent plugs to allow the gases that form within the cells to escape. The plates in the battery are the cathodes and anodes. In Figure 4-8, the negative plate group is the cathode of the individual cells, and the positive plate group is the anode. The plates are interlaced with a terminal attached to each plate group. The terminals of the individual cells are connected together by link connectors, as shown in Figure 4-7. The cells are connected in series in the battery and the positive terminal of the battery. The negative terminal of the opposite end cell becomes the negative terminal of the battery.

The terminals of a lead-acid battery are usually identified from one another by their size and markings. The positive terminal, marked (+), is sometimes colored red and is physically larger than the negative terminal, marked (-). The individual cells of the lead-acid battery are not replaceable; so if one cell fails, the battery must be replaced.

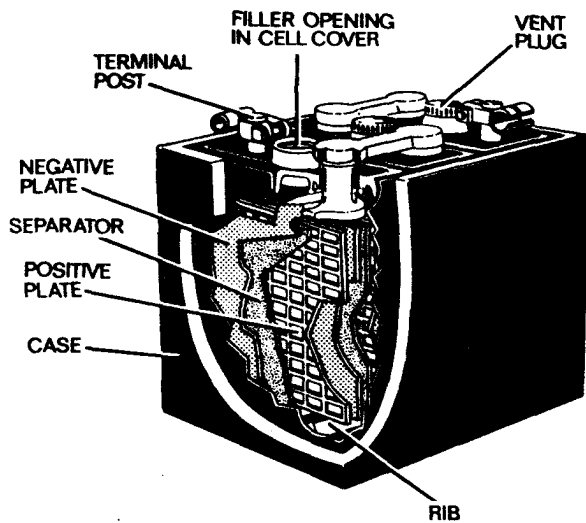


FIGURE 4-7. Lead-Acid Battery Construction.

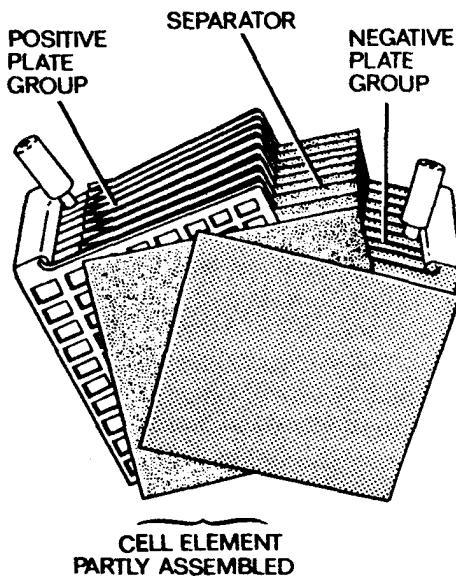


FIGURE 4-8. Lead-Acid Battery Plate Arrangement.

The nickel-cadmium battery is similar in construction to the lead-acid battery, except that it has individual cells that can be replaced. Figure 4-9 shows the cell of the NICAD battery.

The construction of secondary cell batteries is so similar that it is difficult to distinguish the type of battery by simply looking at it. The type of battery

must be known to properly check or recharge the battery. Each battery should have a nameplate that gives a description of its type and electrical characteristics.

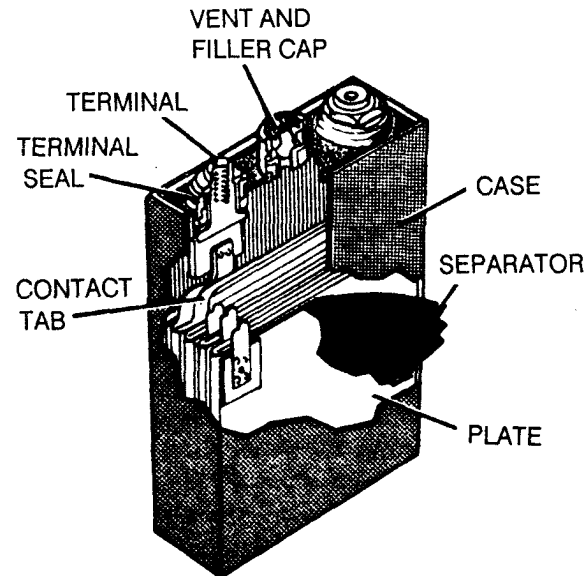


FIGURE 4-9. Nickel-Cadmium Cell.

BATTERY MAINTENANCE

The transportation field relies on the battery's ability to store electrical power until such time as the power is needed. Army watercraft personnel use the battery not only for diesel starting, but as an emergency source of power on watercraft during an electrical casualty. The general information below concerns the maintenance of secondary-cell batteries, in particular the lead-acid battery. Refer to the appropriate technical manual before engaging in any other battery maintenance.

Leak Test

Cleanliness of the lead-acid battery is a primary concern because moisture and dirt are conductors. Batteries that are allowed to gas excessively add additional conductive liquid to the top and sides of the battery. Damp battery surfaces retain conductive dirt and debris.

A simple test, known as the leak test, provides a visual and authoritative point of view for battery cleanliness. Figure 4-10 illustrates the procedure.

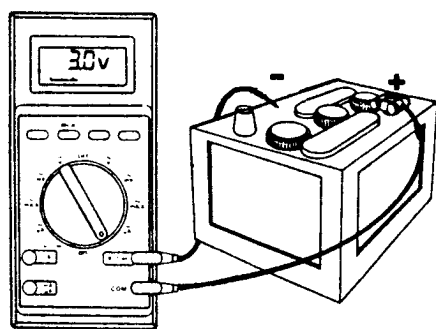


FIGURE 4-10. Leak Test.

(1) Select a DC voltage scale at or above battery voltage.

(2) Connect the negative meter lead to the negative battery post (the smaller battery post).

(3) Use the positive meter lead to probe the housing of the battery.

(4) Measure the voltage leaking across the two battery terminals using the multimeter.

In effect, electrolyte, dirt, and other foreign matter become a parallel circuit that continuously discharges the battery. Grease is not an acceptable battery terminal preservative. The heat from the battery compartment often melts the grease, which in turn covers the top and sides of the battery with a thin coating of lubricant. Dirt and dust adhere easily to this surface.

Idle Winter Batteries

Battery maintenance becomes even more critical during the winter months. The cold weather increases the already difficult task of starting diesel engines. Since the starter motor rotates slower than normal, less counter EMF is developed, and the current to the starter motor remains high. This increased current depletes the storage batteries rapidly. Problems are readily observed after extended winter weekends. To ensure the batteries are maintained at a high state of readiness –

- Always service and charge batteries thoroughly whenever the batteries are to

enter an idle period. A discharged battery will freeze at about 18 degrees Fahrenheit. A frozen battery greatly increases the chance of a battery detonation. Detonation occurs during excessive charging or prolonged efforts to jump start equipment under these severe conditions.

- After the batteries are serviced and charged, disconnect the cables. Always disconnect the negative battery post first. Many small electrical problems in the starting or charging system can conduct current and discharge the batteries. When the equipment is operated regularly, small electrical deficiencies may not be noted. However, when equipment is left idle, even for a short time, these electrical deficiencies become apparent.

Battery Maintenance Tools

The most acceptable manner to clean battery terminals and clamps is to use the cutter or straightedge type of battery terminal and clamp cleaner. Wire-type battery terminal and clamp cleaners can damage the battery posts and clamps. Figure 4-11 shows the physical differences between the two cleaners.

Figure 4-12 view A shows a battery terminal in dire need of cleaning. The main concern for cleaning is to provide a large, clean contact surface area for the unimpeded flow of current. In view B, a cutter-type terminal cleaner is used. The cutter-type cleaner ensures a concentric post surface uniform in

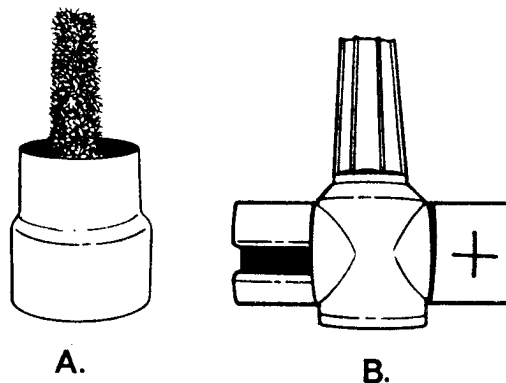


FIGURE 4-11. Battery Terminal and Clamp Cleaners.

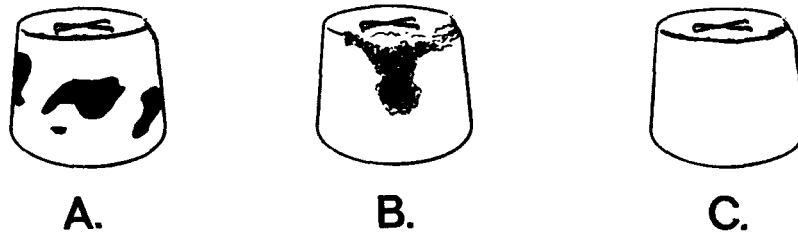


FIGURE 4-12. Cleaning a Dirty Battery Terminal.

contact area. The cutter leaves some of the surface area soiled and dull because it is designed to maintain the original taper of both the post and the clamp. The cutter can only remove a small amount of the outer post surface area each time. The low pitted areas grow smaller in dimension as the tool is used.

(A) Dirty Battery Terminal.

(B) Battery Terminal Partly Cleaned With Cutter-Type Terminal Cleaner.

(C) Battery Terminal Cleaned With Cutter-Type Terminal Cleaner.

When the inside of the terminal clamp is cleaned with the cutter-type cleaner, a similar condition results (Figure 4-13). Pits are visible and continually reduced in size. The cutting can continue until a uniform and properly tapered clean surface results.

(A) Dirty Battery Clamp.

B) Partly Cleaned Battery Clamp With Cutter-Type Cleaner.

(C) Cleaned Battery Clamp With Cutter-Type Cleaner.

The wire-type cleaner cannot restore the surface of the post or clamp. It will clean the entire area, but it cannot restore any irregularities in the surfaces. It actually increases the surface distortions. Pits get bigger, and the necessary contact surface area is decreased. The original taper is lost. The surface area is eventually reduced to a point where excessive heat from current flow can melt the post and clamp. A spark may result, detonating the

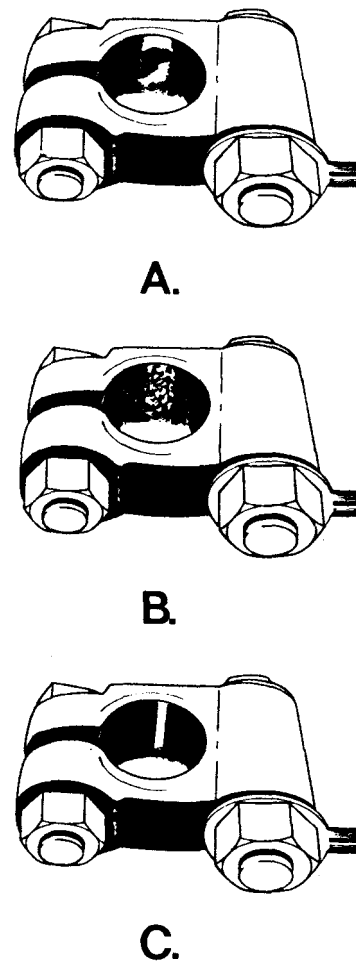


FIGURE 4-13. Cleaning a Dirty Battery Clamp.

battery. As Figure 4-14 shows, reduced contact area equals increased heating.

Use a battery terminal clamp puller to remove battery clamps from the terminals. Prying the clamp from the terminal with a screwdriver will damage the terminal.

Battery Log

Keep weekly specific gravity readings and overall battery bank voltage readings in a battery logbook. This will provide an accurate and complete operational status of each battery to forecast any cells that are becoming deficient. Figure 4-15 is an example of a battery logbook.

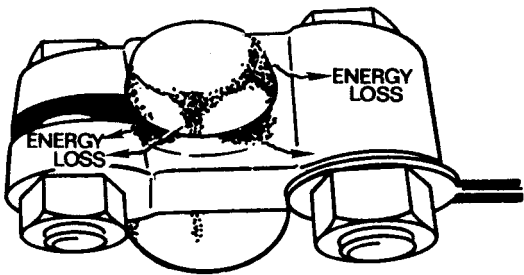


FIGURE 4-14. Reduced Contact Area Equals Increased Heating.

Date Serviced:	
Battery No. 1:	Battery No. 2:
Date Installed:	Date Installed:
Specific Gravity Readings (negative to positive terminal)	
Cell 1: _____	Cell 4: _____
Cell 2: _____	Cell 5: _____
Cell 3: _____	Cell 6: _____

Battery No. 3:		Battery No. 4:	
Date Installed:		Date Installed:	
Cell 1: _____	Cell 4: _____	Cell 1: _____	Cell 4: _____
Cell 2: _____	Cell 5: _____	Cell 2: _____	Cell 5: _____
Cell 3: _____	Cell 6: _____	Cell 3: _____	Cell 6: _____

Battery No. 5:		Battery No. 6:	
Date Installed:		Date Installed:	
Cell 1: _____	Cell 4: _____	Cell 1: _____	Cell 4: _____
Cell 2: _____	Cell 5: _____	Cell 2: _____	Cell 5: _____
Cell 3: _____	Cell 6: _____	Cell 3: _____	Cell 6: _____

FIGURE 4-15. Battery Logbook.

The Hydrometer

A hydrometer is the instrument that measures the amount of active ingredients in the electrolyte of the battery. The hydrometer measures the specific gravity of the electrolyte. Specific gravity is the ratio of the weight of the electrolyte to the weight of the same volume of pure water. The active ingredient, such as sulfuric acid or potassium hydroxide, is heavier than water. Therefore, the more active ingredient there is in the electrolyte, the heavier the electrolyte will be. The heavier the electrolyte is, the higher the specific gravity will be.

WARNING

Never mix lead-acid and nickel cadmium servicing tools together. Never store or transport nickel-cadmium and lead-acid batteries together. The combination of potassium hydroxide and sulfuric acid electrolytes generate a toxic gas that can kill!

A hydrometer (Figure 4-16) is a glass syringe with a float inside it. The float is a hollow glass tube weighted at one end and sealed at both ends, with a scale calibrated in specific gravity marked on the side. The electrolyte to be tested is drawn into the hydrometer by using the suction bulb. Enough electrolyte should be drawn into the hydrometer so that the float will rise. However, the hydrometer should not be filled to the extent that the float rises into the suction bulb. Since the weight of the float is at its base, the float will rise to a point determined by the weight of the electrolyte. If the electrolyte contains a large concentration of active ingredient, the float will rise higher than if the electrolyte has a small concentration of active ingredient.

To read the hydrometer, hold it in a vertical position and take the reading at the level of the electrolyte. Refer to the manufacturer's technical manual for battery specifications for the correct specific gravity ranges.

WARNING

Care must be taken to prevent electrolytes from entering the eyes or from splashing on the skin.

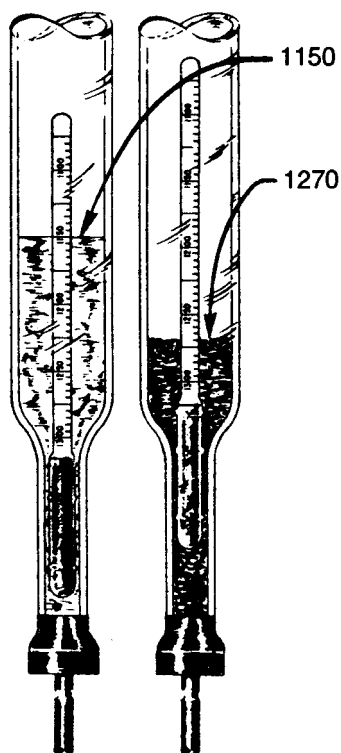


FIGURE 4-16. Hydrometer.

NOTE: Hydrometers should be flushed with fresh water after each use to prevent inaccurate readings. Storage battery hydrometers must not be used for any other purpose.

State of Charge

Table 4-1 provides a general guidance for the specific gravity of the lead-acid battery.

All testing of battery-powered equipment must be conducted with fully charged batteries. The manufacturer's technical data is based on the assumption that the power supply (batteries) is fully operational. Any deviation from the fully charged condition will change the testing results. If the batteries are not fully charged, the test results will be erroneous and inconclusive.

Unless otherwise specified, the specific gravity readings between cells should be no greater than 30

TABLE 4-1. Specific Gravity of the Lead -Acid Battery

Specific Gravity Temperate Climates	Specific Gravity Tropical Climates	State of Charge
1.260 - 1.280	1.225	Fully Charged
1.230 - 1.250	1.195	75 Percent Charged
1.200 - 1.220	1.165	50 Percent Charged
1.170 - 1.190	1.135	25 Percent Charged
1.110 - 1.130	1.075	Discharged

points (.030). Any variations outside the specifications indicate an unsatisfactory condition, and the battery should be replaced.

Gassing

When a battery is being charged, a portion of the energy breaks down the water in the electrolyte. Hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on charge, the charging rate is too high. If the rate is not too high, steady gassing develops as the charging proceeds, indicating that the battery is nearing a fully charged condition.

Avoid excessive gassing. The by-products are hazardous and explosive. Any lost liquid from the battery cell is a combination of water and sulfuric acid. Since the specific gravity changes as the batteries increase in charge, it is impossible to anticipate the exact content of sulfuric acid removed from the cell. Every time the maintenance technician replenishes the cell with water, he is actually reducing the percentage of sulfuric acid within that cell. Eventually the chemical action will become deficient.

Battery Caps

When taking hydrometer readings, avoid contaminating battery cap undersides by placing them upside down on the battery case. This will help keep debris from falling into the cell.

Troubleshooting Battery-Powered Systems

Troubleshooting battery-powered systems can become complex. Unlike many mechanical systems, numerous electrical problems can be identified with a good initial inspection. Burned out electrical components have a distinctive electrical smell, and charred wires and connections are readily identified. Once these areas are identified and corrected, further tests are needed to determine the reason for this condition.

Check all connections, from the battery throughout the entire electrical system, regularly. All connections must be clean and tight. Army vessels operating in the salt air environment are especially prone to oxidation. All mobile units are prone to vibration. Together, vibration and oxidation account for a large percentage of electrical malfunctions.

Any increase in resistance in the circuit reduces the current throughout the entire circuit. When current is reduced, the magnetic properties of the circuit are reduced. Current is a quantity of electrons (with their magnetic field) passing a point in the circuit in a period of time. With fewer electrons, there is a reduction in the magnetic properties available to the circuit components. With a reduction of electrons (and their magnetic influence), motors, solenoids, and other electrical components will function irregularly. Some of the more obvious resistance increases are due to improper or dirty connections and corroded cable ends.

To understand how a small amount of additional resistance can reduce the capability of the electrical system, suppose that a resistance of 1 ohm exists in a poorly made connection in a diesel engine starting system. The 24-volt battery starting system normally provides 240 amps to a starting system with a resistance of .1 ohms. The 24 volts must now supply a starting system with 1.1 ohms resistance.

The additional 1 ohm resistance will consume power (power = amps x volts). The current will be reduced because the total resistance (R_t) is increased. The total amperage for the system is reduced as shown in the following equation:

$$I_t = \frac{E_t}{R_t}$$

$$I_t = \frac{24 \text{ volts}}{1.1 \text{ ohm}}$$

$$I_t = 21.8 \text{ amps}$$

The 240 amps required to turn the starter motor has been reduced to 21.8 amps. The starter cannot turn.

Battery Voltage

A fully charged lead-acid battery has 2.33 volts per cell. It is quite common for a 24-volt battery bank to actually have a voltage of 26.5 volts. The technical manual specifies the term "battery voltage" instead of 24 volts because the actual battery terminal voltage must be observed throughout the entire electrical testing procedure. The manufacturer is concerned with the actual battery bank voltage.

A charged battery that shows an extremely high voltage is suspect of being deficient. Individual 12-volt batteries should not exceed 15.5 volts, and 6-volt batteries should not exceed 7.8 volts. If these voltages are exceeded, the battery is unsatisfactory and probably sulfated. These higher voltage values indicate only a superficial charge and are incapable of delivering the current capacity designed for the battery.

Test result standards are based on a fully functioning power supply. Always start

troubleshooting the battery-powered electrical system at the batteries. The batteries must be fully operational and completely charged before testing any other electrical component. Charge the existing battery bank or substitute the batteries when other circuit components are suspect.

Other Maintenance

Perform routine maintenance of batteries regularly. Check terminals periodically for cleanliness and good electrical connections. Inspect the battery case for cleanliness and evidence of damage. Check the level of electrolyte. If the electrolyte is low, add distilled water to bring the electrolyte to the proper level. Maintenance procedures for batteries are normally determined by higher authority. Each command will have detailed procedures for battery care and maintenance.

Safety Precautions With Batteries

Observe the following safety precautions when working with batteries:

- Handle all types of batteries with care.
- Never short the terminals of a battery.
- Use carrying straps when transporting batteries.
- Wear chemical splash-proof safety glasses when maintaining batteries.
- Wear protective clothing, such as a rubber apron and rubber gloves when working with batteries. Electrolyte will destroy everyday clothing such as the battle dress uniform.
- Do not permit smoking, electric sparks, or open flames near charging batteries.
- Take care to prevent spilling the electrolyte.
- Never install alkaline and lead-acid batteries in the same compartment.
- Do not exchange battery tools to include hydrometers between lead-acid batteries and nickel-cadmium batteries.

In the event electrolyte is splashed or spilled on a surface, such as the deck or table, immediately dilute it with large quantities of water and clean it up.

If the electrolyte is spilled or splashed on the skin or eyes, immediately flush the area with large quantities of fresh water for a minimum of 15 minutes. If the electrolyte is in the eyes, be sure the upper and lower eyelids are pulled out sufficiently to allow the fresh water to flush under the eyelids. Notify the medical department of the type of electrolyte and the location of the accident as soon as possible.

CAPACITY AND RATING OF BATTERIES

The capacity of a battery is measured in ampere-hours. The ampere-hour capacity equals the product of the current in amperes and the time in hours during which the battery will supply this current. The ampere-hours capacity varies inversely with the discharge current. For example, a 400 ampere-hour battery will deliver 400 amperes for one hour or 100 amperes for four hours.

Storage batteries are rated according to their rate of discharge and ampere-hour capacity. Most batteries are rated according to a 20-hour rate of discharge. That is, if a fully charged battery is completely discharged during a 20-hour period, it is discharged at the 20-hour rate. Thus, if a battery can deliver 20 amperes continuously for 20 hours, the battery has a rating of 20 amperes x 20 hours, or 400 ampere-hours. Therefore, the 20-hour rating equals the average current that a battery can supply without interruption for an interval of 20 hours.

All standard batteries deliver 100 percent of their available capacity if discharged in 20 hours or more, but they will deliver less than their available capacity if discharged at a faster rate. The faster they discharge, the less ampere-hour capacity they have.

The low-voltage limit, as specified by the manufacturer, is the limit beyond which very little useful energy can be obtained from a battery. This low-voltage limit is normally a test used in battery shops to determine the condition of a battery.

BATTERY CHARGING

Adding the active ingredient to the electrolyte of a discharged battery does not recharge the battery.

Adding the active ingredient only increases the specific gravity of the electrolyte. It does not convert the plates back to active material, and so does not bring the battery back to a charged condition. A charging current must be passed through the battery to recharge it.

WARNING

A mixture of hydrogen and air can be dangerously explosive. No smoking, electric sparks, or open flames should be permitted near charging.

Types of Charges

The following types of charges may be given to a storage battery, depending on the condition of the battery

- Initial charge.
- Normal charge.
- Equalizing charge.
- Floating charge.
- Fast charge.

Initial Charge. When a new battery is shipped dry, the plates are in an uncharged condition. After the electrolyte has been added, it is necessary to charge the battery. This is done by giving the battery a long low-rate initial charge. The charge is given according to the manufacturer's instructions, which are shipped with each battery. If the manufacturer's instructions are not available, refer to the detailed instructions for charging batteries found in TM 9-6140-200-14.

Normal Charge. A normal charge is a routine charge given according to the nameplate data during the ordinary cycle of operation to restore the battery to its charged condition.

Equalizing Charge. An equalizing charge is a special extended normal charge that is given periodically to batteries as part of maintenance routine. It ensures that all sulfate is driven from the plates and that all the cells are restored to a maximum specific

gravity. The equalizing charge is continued until the specific gravity of all cells, corrected for temperature, shows no change for a four-hour period.

Floating Charge. In a floating charge, the charging rate is determined by the battery voltage rather than by a definite current value. The floating charge is used to keep a battery at full charge while the battery is idle or in light duty. It is sometimes referred to as a trickle charge and is done with low current.

Fast Charge. A fast charge is used when a battery must be recharged in the shortest possible time. The charge starts at a much higher rate than is normally used for charging. It should be used only in an emergency, as this type charge may harm the battery.

Charging Rate

Normally, the charging rate of storage batteries is given on the battery nameplate. If the available charging equipment does not have the desired charging rates, use the nearest available rates. However, the rate should never be so high that violent gassing occurs.

Charging Time

Continue the charge until the battery is fully charged. Take frequent readings of specific gravity during the charge and compare with the reading taken before the battery was placed on charge.